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by

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13. ABSTRACT

The fluxes and spectra of solar protons in the energy range 1-100 MeV have been measured over the earth's polar caps at an altitude of 800 km aboard the satellite 1971-089A during the intense solar particle events of 3-12 August 1972. Differential proton fluxes in the energy intervals 1-4.5 MeV, 5-20 MeV and 20-100 MeV are presented as a function of time throughout the events. The fluxes of 0.76-2.1 MeV energetic electrons are also presented. Differential spectra of protons, alpha particles and electrons over the south central polar cap are shown for 1102 UT on 4 August and 0144 UT on 9 August 1972. Comparisons of the peak and integrated fluxes measured in this experiment with another measurement made during these events and with other large events in the previous solar cycle have been made. The 29-100 MeV proton fluxes measured over the polar caps in this experiment are in good agreement with the greater than 30-MeV proton measurements of Bostrom et al. (1972) made in interplanetary space and in the magnetosphere. The present data indicate that the 4 August 1972 event was the largest solar particle event observed near earth in the last two decades.



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## Abstract

The fluxes and spectra of solar protons in the energy range 1-100 MeV have been measured over the earth's polar caps at an altitude of 800 km aboard the satellite 1971-089A during the intense solar particle events of 3-12 August 1972. Differential proton fluxes in the energy intervals 1-4.5 MeV, 5-20 MeV and 20-100 MeV are presented as a function of time throughout the events. The fluxes of 0.76-2.1 MeV energetic electrons are also presented. Differential spectra of protons, alpha particles and electrons over the south central polar cap are shown for 1102 UT on 4 August and 0144 UT on 9 August 1972. Comparisons of the peak and integrated fluxes measured in this experiment with another measurement made during these events and with other large events in the previous solar cycle have been made. The 29-100 MeV proton fluxes measured over the polar caps in this experiment are in good agreement with the greater-than-30 MeV proton measurements of Bostrom et al (1972) made in interplanetary space and in the magnetosphere. The present data indicate that the 4 August 1972 event was the largest solar particle event observed near earth in the last two decades.

## Introduction

During the intense solar flares of early August 1972, the fluxes and spectra of solar protons, electrons and alpha particles were measured over the earth's polar caps at 800 km altitude with the Lockheed experiment aboard the polar orbiting satellite 1971-089A. The experiment contains a comprehensive collection of low and high energy particle detectors as well as an earth-reflection-ionospheric sounder (ERIS). Data were collected on nearly every polar cap crossing during the period 3-12 August by means of on-board tape recorders.

The data presented in this preliminary report are from the high-energy-proton spectrometer (HEPS) in this experiment. This instrument, which has been described in detail elsewhere (Reagan et al, 1972), is a multi-element silicon detector stack mounted within a plastic scintillator guard counter to form a particle telescope that is oriented at $20^{\circ}$ to the zenith to observe precipitating particles. The energy spectra of protons from 1.0-100 MeV, electrons from 0.76-2.1 MeV and alpha particles from 6-400 MeV are measured in four time-shared modes of operation with 256-channel pulse-height resolution. Counting rates from each of the main elements of the telescope and the guard counter corresponding to these modes are measured every 32 ms. Digital samples of individual pulse height data are made at the rate of 1024 samples/sec such that statistically meaningful spectra of all three particle types over the above energy ranges are obtained every several seconds. An identical spectrometer (HEAPS) is oriented at $90^{\circ}$ to the zenith to observe mirroring particles.

Differential flux profiles of protons and electrons over the polar caps in several energy intervals have been processed and analyzed to date. In addition, the

energy spectra of the protons, electrons and alpha particles have been generated at several different times throughout the events. Peak and integrated proton fluxes have been compared to previous large solar events in the present and previous solar cycles. The present polar cap data for the period 3-7 August clearly indicate that this event was the most intense and energetic observed at the earth in the last two decades.

## Flux Profiles

The differential flux of protons in the 1-4.5 MeV energy range throughout the 3-13 August period is shown in Figure 1. The data shown have been taken from approximately 150 north and south polar cap crossings that occur every 50 minutes. The data points correspond to measurements taken near the maximum magnetic latitude of each polar pass and represent either 32 ms or 250 ms time averages. Averaging of the data over longer time intervals, which is in progress, will result in smoother profiles since some variations in the flux are observed on many polar cap crossings. On a few occasions large flux depressions were observed over the high latitude south polar cap (Reagan et al, 1973). In these cases, the lower latitude flux values have been selected as being more representative of the flux incident on the magnetosphere.

Examination of the spectra of all three particle types indicates that the spectrometer functioned normally throughout the entire period. On a few polar passes at the peak of the event when the combined counting rates in the spectrometer exceeded $10^5$ counts/sec, some shifting of the spectrum was observed due to pile-up effects. Corrections for pile-up were applied in these cases. In particular, careful examination of the data has been made to assure that the intense fluxes of

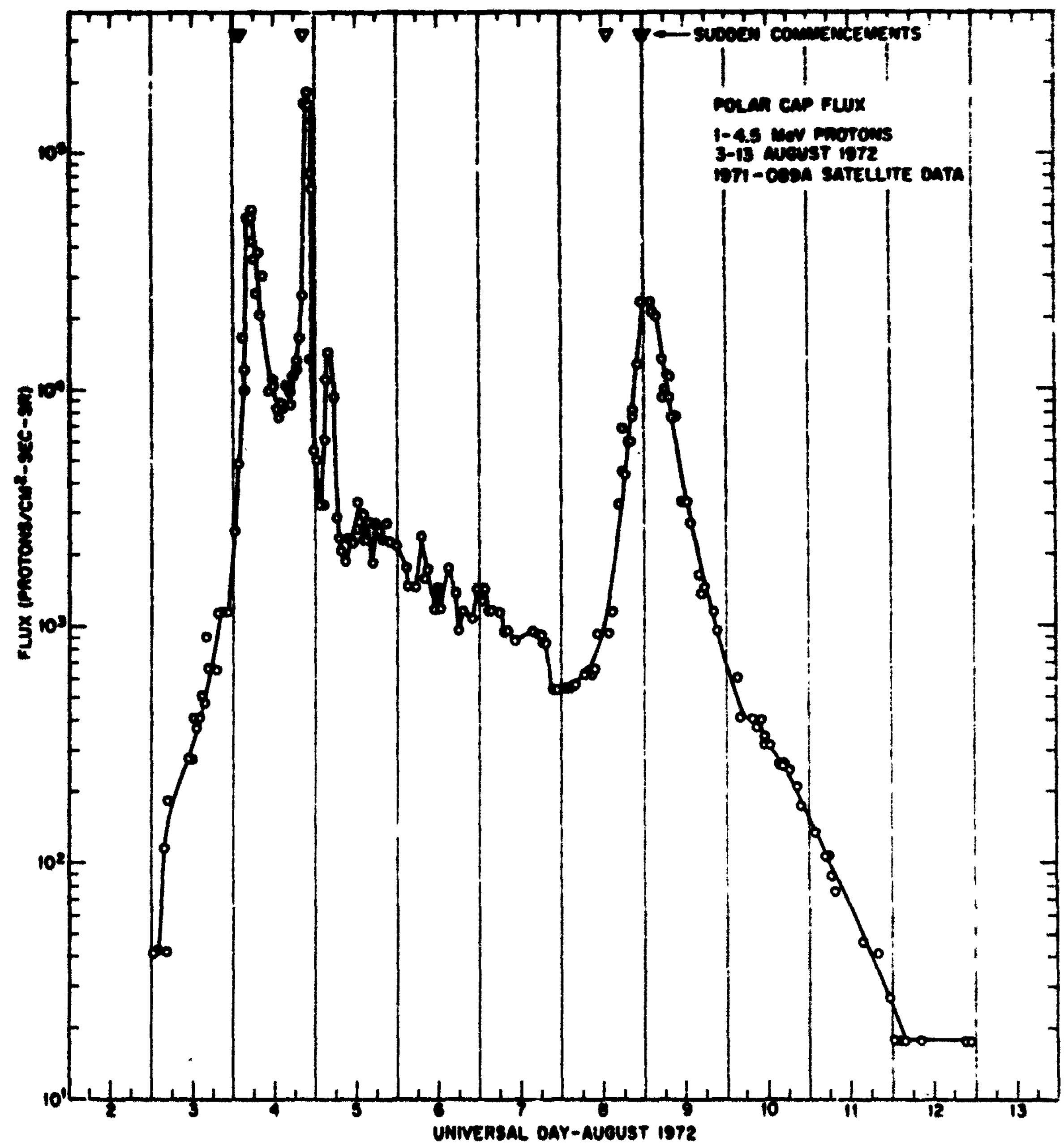


Figure 1. Differential flux of 1-4.5 MeV protons as measured by the Lockheed spectrometer on the 1971-089A satellite during the 3-13 August 1972 solar particle events.

energetic electrons present during these events were not contaminating the proton measurements. In no case was this evident. The spectra of the in-flight calibration sources (Am-241) in each detector reveal that no gain shifts of greater than 2 percent have occurred since launch, including the period of these events. Dead-time and chance-coincidence corrections amounting to no greater-than-25 percent at the peak have been applied to the data. Cosmic-ray and calibration-source backgrounds have been subtracted.

The flux profile of these lower energy protons reveals several interesting features. The flux of these protons over the polar caps was substantial even as early as 0050 UT on 3 August, some 24-hours prior to the arrival of the high energy protons associated with the large event of 4 August. These lower energy protons probably resulted from the flare of 2B importance that occurred in McMath Region 11976 at 1958 UT on 2 August (Lincoln and Leighton, 1972). The 1-4.5 MeV protons reached an initial peak flux of $5.7 \times 10^4$ protons/cm$^2$-sec-sr at 0530 UT on 4 August. Sudden storm commencements as reported by NOAA (Lincoln and Leighton, 1972), and indicated at the top of Figure 1, occurred at 0119 and 0220 UT on 4 August. The flux decreased exponentially over the next 10 hours but at $\sim$ 1600 UT began to rise sharply to a peak value of $1.85 \times 10^5$ protons/cm$^2$-sec-sr at $\sim$ 2200 UT on 4 August. Examination of the higher energy proton and electron data show that the peak flux at all energies occurred at approximately this time. A sudden commencement occurred at 2054 UT. This intense peak is most probably associated with the flare of 3B importance that occurred at 0530 UT on 4 August 1972 in McMath Region 11976 (Lincoln and Leighton, 1972). The rise and fall of the protons near the peak was so rapid that large temporal variations in the flux ( $\sim$ x 10) were observed over the approximately 15 minute time interval of a polar cap crossing.

At ~ 0300 UT on 5 August a peculiar increase in the proton flux occurred. The flux profile between ~ 0300 and ~ 0530 UT has the characteristics of a well-defined square wave as observed over the polar caps. The phenomenon is observed at all energies and particle types measured in the spectrometer. Comparison of the polar-cap temporal profile with interplanetary data indicates that the south polar cap flux decreased some 23 minutes later than the interplanetary flux (Reagan et al, 1973). This phenomenon is currently under study and will be reported at a later time.

Following the above phenomenon, the 1-4.5 MeV proton flux continued to decrease in an exponential manner over the next three days. The structure observed in the data results from observed variations across the polar cap as a result of magnetospheric access, from variations in the interplanetary flux and from the statistical spread associated with the 250 ms averaging. At ~ 1200 UT on 8 August the 1-4.5 MeV protons most probably associated with the flare of 3B importance that occurred in McMath region 11976 at 1455 UT on 7 August arrived over the polar caps. The flux increased over the next 12 hours to a peak value of $2.4 \times 10^4$ protons/cm$^2$-sec-sr at ~ 0030 UT on 9 August. Following the peak, the protons decreased in an exponential manner with an e-fold value of 5.5 hours.

The profile of the 5-20 MeV protons shown in Figure 2 is similar to the lower-energy protons. An initial peak of $9 \times 10^3$ protons/cm$^2$-sec-sr was observed at 0530 UT on 4 August. The main peak which occurred at ~ 2200 UT 4 August reached an intensity of $8 \times 10^4$ protons/cm$^2$-sec-sr. As mentioned above, the peculiar peak between 0300-0530 UT on 5 August is clearly evident in these data also. The peak of the second large event occurred at ~ 0000 UT on 9 August at a flux level of $1.4 \times 10^4$ protons/cm$^2$-sec-sr.

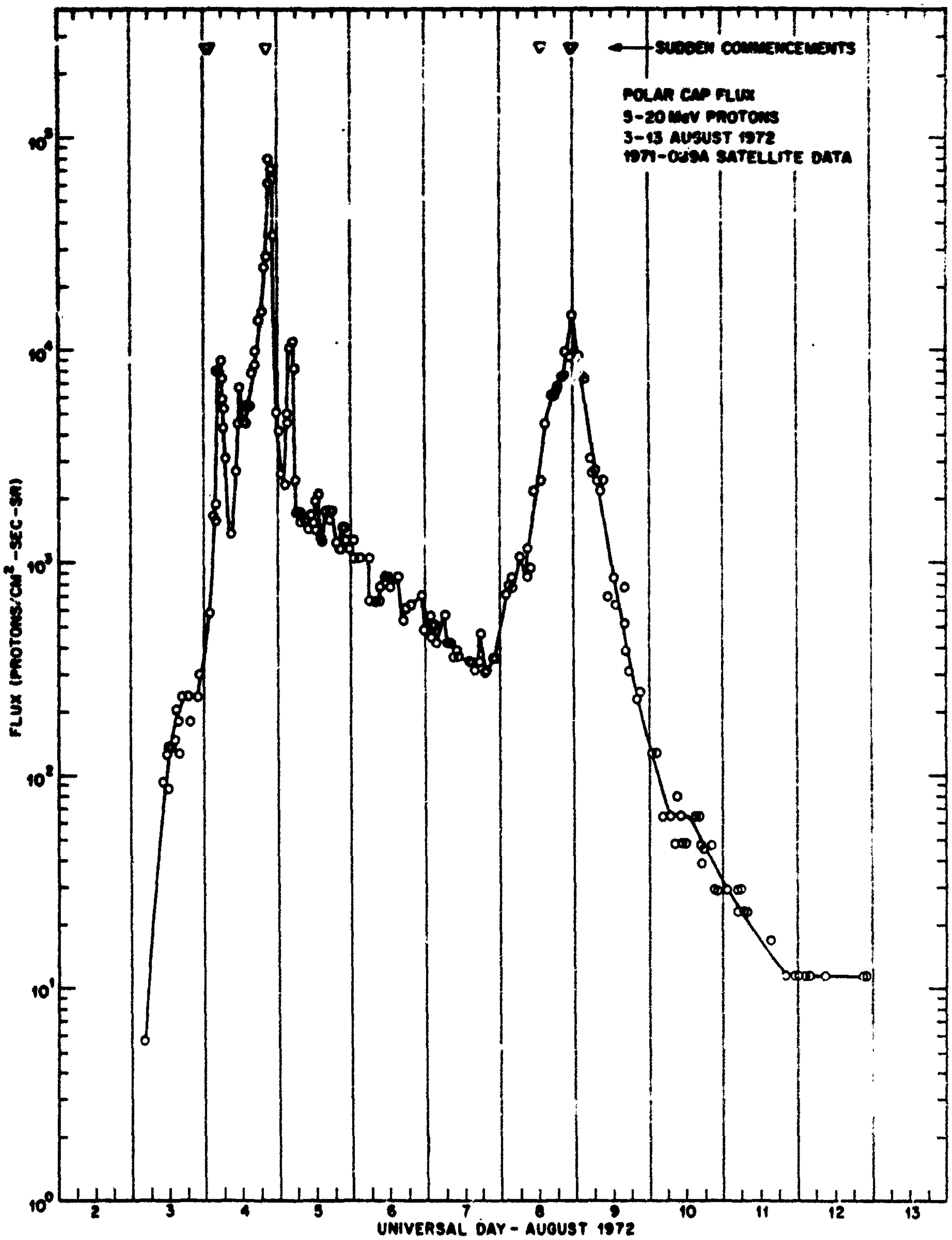


Figure 2. Differential flux of 5-20 MeV protons as measured by the Lockheed spectrometer on the 1971-089A satellite during the 3-13 August 1972 solar particle events.

Figure 3 shows the time profile of the energetic protons between 29-100 MeV. This profile has significant differences when compared with the previous two profiles. First of all, energetic protons were not present over the polar caps prior to ~ 0530 UT on 4 August. The solar flares in McMath region 11976 prior to the 3B event at 0530 UT on 4 August apparently did not produce energetic protons that reached the earth. The 29-100 MeV protons that arrived shortly after 0530 UT increased to a broad peak between 1530 and 2200 UT on 4 August at an intensity of $2.4 \times 10^4$ protons/$cm^2$-sec-sr. The flux dropped over an order of magnitude in the two-hour period following the major peak and was then beginning to decay exponentially when the peculiar event of 5 August, which is quite pronounced even at these energies, occurred. The flux continued to decay in an exponential manner with an e-fold value of ~ 18 hours out to ~ 1700 UT on 7 August. At this time, the high energy protons and energetic electrons from the flare that occurred at 1455 UT on 7 August began to arrive over the polar caps. This particle event was more typical of a classical event in which the higher energy protons with higher transit velocity arrive at the earth followed by the lower energy protons. The major event of 4 August was complicated in this regard by the presence of significant fluxes of lower energy protons from earlier events. The energetic protons peaked at ~ 0500 UT on 8 August at a value of $4 \times 10^2$ protons/$cm^2$-sec-sr. From comparison of Figures 1, 2, and 3 it is immediately evident that this second major event in the period was characterized by a significantly softer proton spectrum. More details on the spectrum will be given later.

Figure 4 shows the time profile of 0.76-2.1 MeV electrons measured during the period 3-9 August. The temporal characteristics of these relativistic electrons

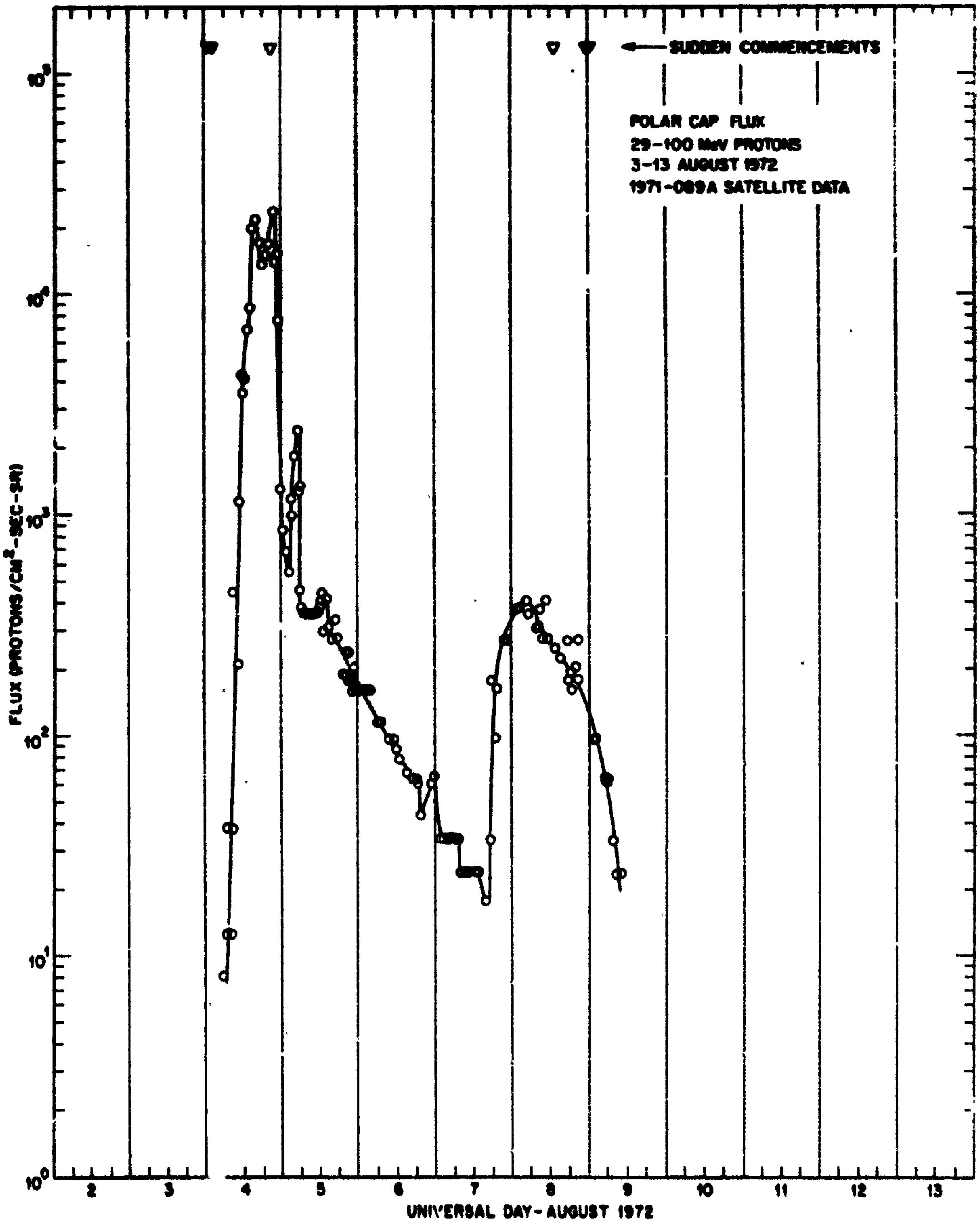


Figure 3. Differential flux of 29-100 MeV protons as measured by the Lockheed spectrometer on the 1971-089A satellite during the 3-13 August 1972 solar particle events.

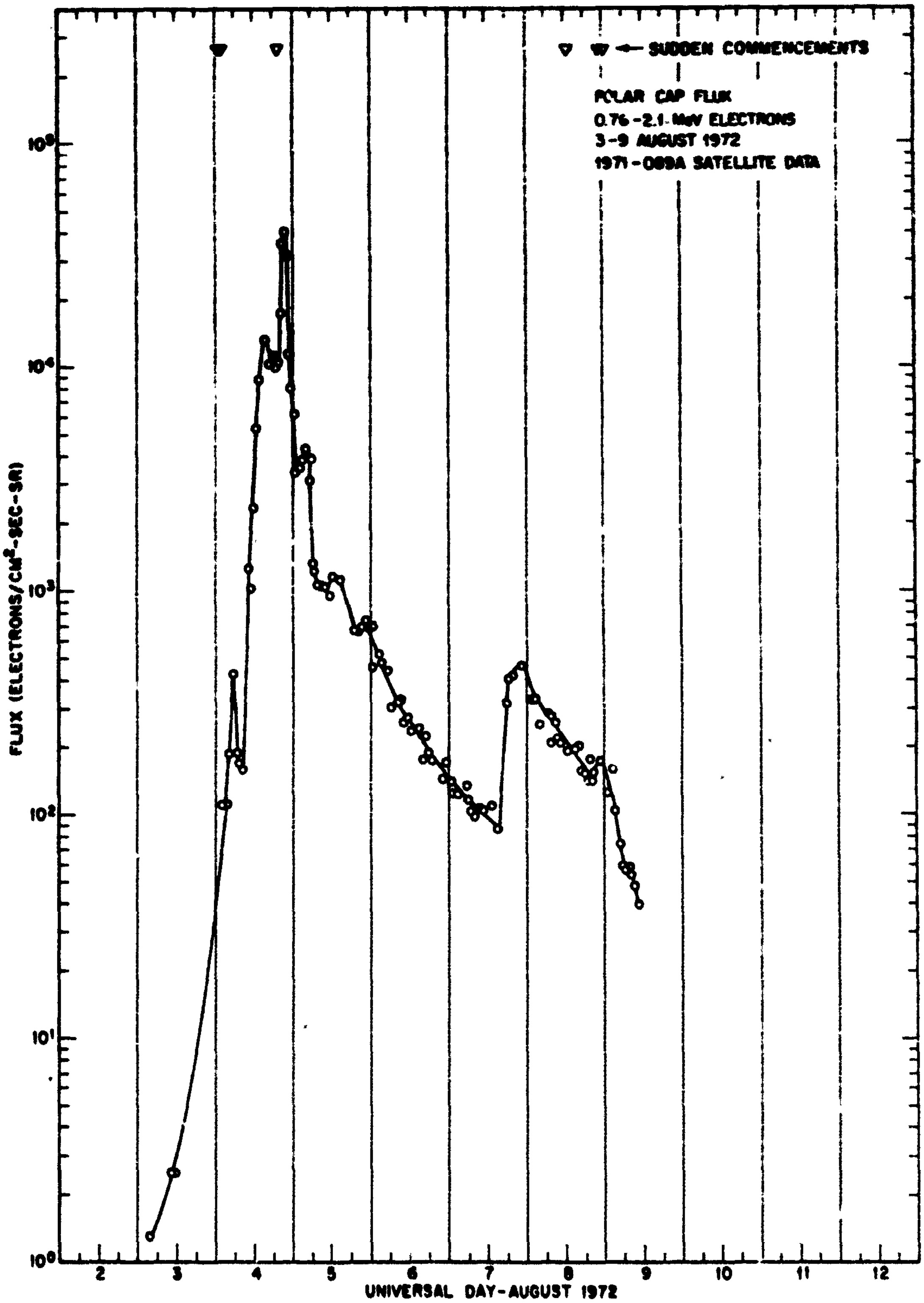


Figure 4. Differential flux of 0.76 - 2.1 MeV electrons as measured by the Lockheed spectrometer on the 1971-089A satellite during the 3-13 August 1972 solar particle events.

are very similar to the energetic protons. The preliminary peak at ~ 0545 UT on 4 August is probably associated with the 3B flare occurrence at 0530 UT that produced an outstanding solar radio emission burst at 0540 UT, (Lincoln and Leighton, 1972). The flux increased to a second peak at ~ 1530 UT and then to a maximum intensity of $4 \times 10^4$ e/cm$^2$-sec-sr at ~ 2200 UT on 4 August. Comparisons with other solar electron events (Lin, 1970) clearly indicate that this is the most intense flux of greater than 800 keV electrons ever observed at the earth in the present solar cycle including the large electron events of 13 April 1969 (West and Vampola, 1971; Burrows, 1971), and 2 November 1969 (Reagan et al, 1971). The effect of these energetic precipitating electrons on ionospheric radiowave absorption is significant and must be considered in addition to the effects of the protons. Also, spacecraft monitors of the solar proton fluxes may be susceptible to these penetrating electrons.

The peculiar event at 0300-0530 UT on 5 August is clearly evident in the electron data also. Following this event, the electrons decayed in a near-exponential manner until ~ 1600 UT on 7 August. At this time the electrons associated with the second major event began arriving over the polar caps. A peak flux of $4.6 \times 10^2$ e/cm$^2$-sec-sr was observed at ~ 2200 UT on 7 August. An obvious feature of this second event is the lower peak intensity of the electrons by approximately two orders of magnitude compared to the 4 August event.

## Spectra

Examination of the temporal flux profiles of the protons shown in Figures 1, 2, and 3 immediately indicates that the spectrum is complex and highly time dependent throughout these events. In the main event of 4 August for example,

a high intensity of lower energy protons (1 - 4.5 MeV) was present over the polar caps from an earlier flare occurrence. After ~ 0600 UT on 4 August, an additional enhancement was observed at all proton energies but especially at the higher energies. The proton spectrum resulting from this combination of time dependent fluxes can therefore be expected to be complex.

In Figure 5 the differential spectra of protons, electrons and alpha particles measured over the south central polar cap in a 250 sec interval at 1102 UT on 4 August are shown. The influence of the arriving energetic protons at this time can be clearly seen in the proton spectrum. The spectrum continues to harden, i.e., to have a relatively higher increase in the intensity of the energetic component compared to the lower energy component, over the next 10 hours. The overall spectrum between 1 and 100 MeV cannot be fit with a single power law dependence but the protons between 1 and 5 MeV can be described by a dependence of the type $n(E) = n_o E^{-1.53}$.

The electron intensity between 0.76 and 2.1 MeV was very high at this time and unlike the protons exhibited a smooth spectral shape. The electron spectrum as shown in Figure 5 could also be well fit with a power dependence having an exponent -1.53 i.e., the electrons possessed the same spectral shape as the lower energy protons. This is a very energetic electron spectrum and significantly harder than ones typically observed in solar particle events. For example, the electron spectrum in the 13 April 1969 event at these energies could be described by a power-law exponent of -3.3 (West and Vampola, 1971) while the 2 November 1969 spectrum was even softer with an exponent of -3.79 (Reagan et al, 1971). The resulting effects of these electrons on the lower ionosphere are significant at these times. A 2 MeV

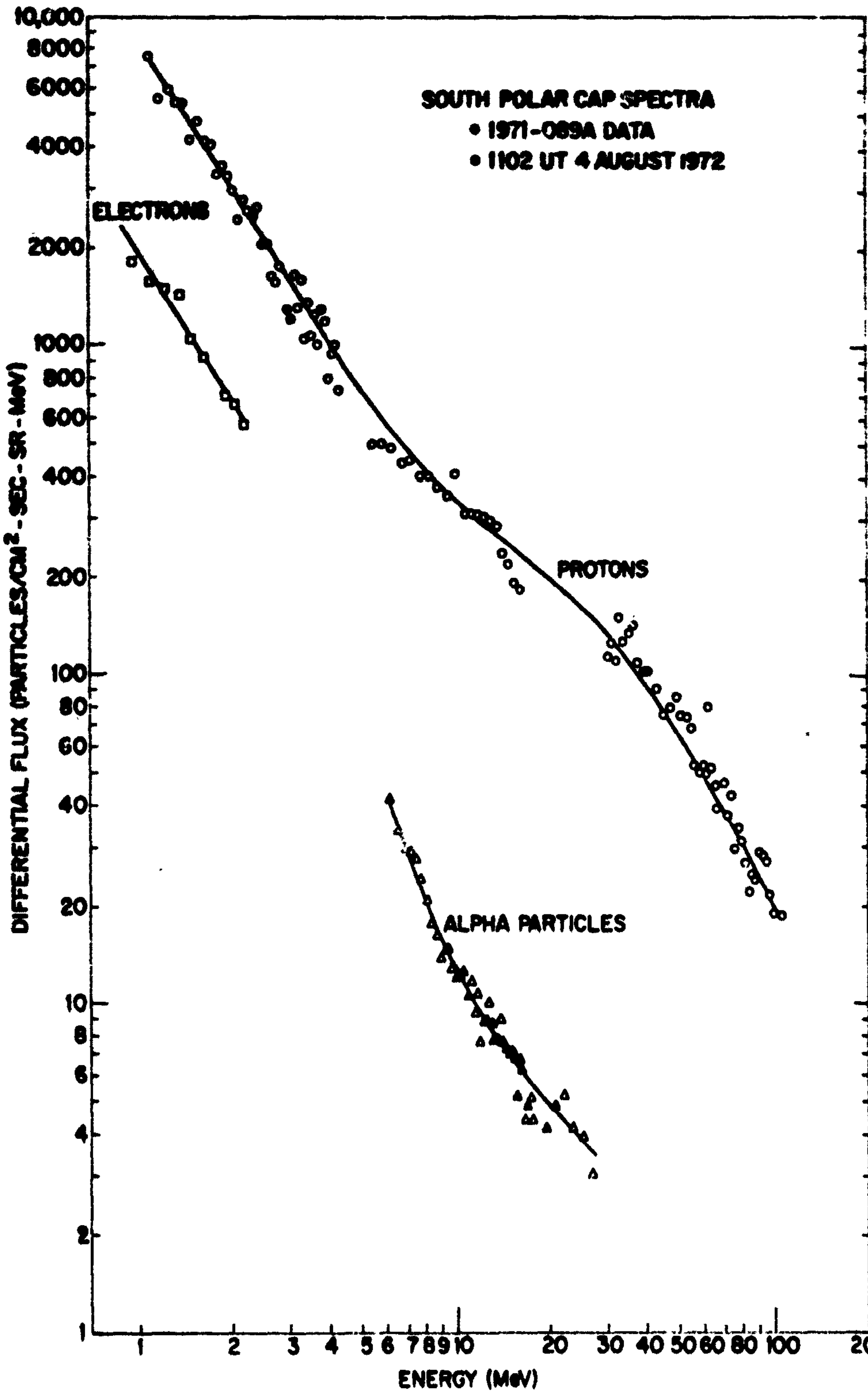


Figure 5. South Polar Cap differential spectra of protons, electrons, and alpha particles measured at 1102 UT on 4 August 1972.

electron, for example, can penetrate the atmosphere to an altitude of approximately 49 km. The electrons in addition to the protons must therefore be considered in terms of the effects of solar particles on radio communication attenuation and blackout. It should be emphasized that these spectra were measured some 10 hours prior to the main peak and that the peak flux at ~ 2100 UT on 4 August is approximately an order of magnitude higher than at 1102 UT.

The alpha particles measured at this time were significantly lower in intensity than either the protons or electrons. The proton to alpha ratio is energy dependent and varies between 17.5 at 7 MeV to 41.5 at 30 MeV. The alpha particles are therefore not as important contributors to ionospheric effects as the protons and electrons.

The spectra of all three particle types over the south central polar cap near the peak of the second major event at 0144 UT on 9 August are shown in Figure 6. Once again, the proton spectrum is too complex to fit with a single power law dependence. The proton spectrum at this time is however much softer than that shown in Figure 5 for 4 August and more typical of solar proton events in the present solar cycle as measured by our group. The electron flux at this time is reduced in intensity by approximately an order of magnitude compared to Figure 5, and the spectrum is softer, being described by a power law with exponent -1.75. The proton-to-alpha flux ratio is approximately 30 at 7 MeV, 20 at 10 MeV, 6 at 20 MeV and only 1.8 at 30 MeV.

Comparisons with Previous Data

The period 3-12 August has been divided into two major solar particle events and the flux profiles shown in Figures 1-4 have been integrated over these intervals

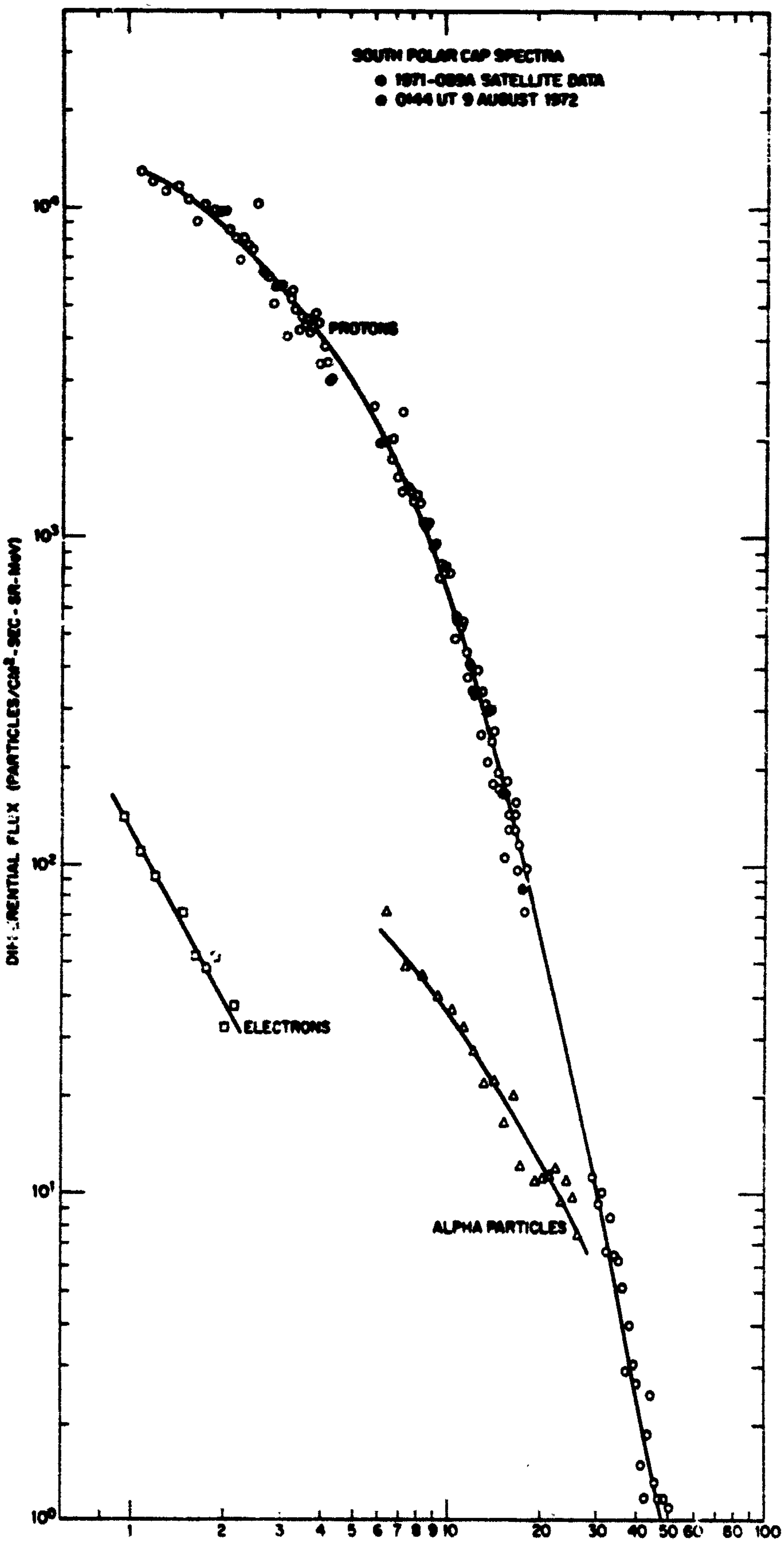


Figure 6. South Polar Cap differential spectra of protons, electrons and alpha particles measured at 0144 UT on 9 August 1972.

for comparison with previous solar particle events observed near the earth during the present and previous solar cycles. The first interval was chosen from 0300 UT 3 August to 1500 UT 7 August. The second interval commences with the arrival of the energetic protons at ~ 1500 UT on 7 August out to 2400 UT on 12 August. In the case of the energetic protons and the electrons, the flux decreased steeply on 9 August and did not significantly contribute to the integral after these times.

Table 1 shows the peak directional and omnidirectional fluxes observed in the various energy ranges for protons and electrons during each of the above time intervals. The omnidirectional fluxes have been obtained from the measured directional fluxes by assuming an isotropic distribution for the solar protons incident on the earth outside the magnetosphere. The measured integrated directional flux and the derived integrated omnidirectional flux are also shown for these time intervals. A peak omnidirectional flux of $2.33 \times 10^6$ protons/$cm^2$-sec and an integrated omnidirectional flux of $4.08 \times 10^{10}$ protons/$cm^2$ for the 1-4.5 MeV protons during the time interval 3-7 August were measured. The 29-100 MeV proton flux measured in this experiment can be compared almost directly with other integral flux measurements of greater-than-30 MeV protons made during this event (Bostrom et al, 1972) and during the large solar particle events in solar cycle 19 (Webber, 1963).

The peak omnidirectional flux of 29-100 MeV protons measured during the period 3-7 August was $2.97 \times 10^5$ protons/$cm^2$-sec. This value agrees quite favorable with the peak integral flux greater-than-30 MeV of $2.6 \times 10^5$ protons/$cm^2$-sec as measured by Bostrom et al, (1972) in interplanetary space for the same time period. The integrated omnidirectional flux in this energy and time interval was

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measured in this experiment to be $8.43 \times 10^9$ protons/$cm^2$. Again, this value agrees quite well with the value $8 \times 10^9$ protons/$cm^2$ quoted by Bostrom et al, (1972) for protons greater-than-30 MeV.

The 4 August 1972 solar particle event is easily the largest event in the present solar cycle. Comparisons of this event with the largest events in the previous solar cycle as reported by Webber (1963) are also shown in Table 1. The largest event in terms of total integrated flux during solar cycle 19 occurred on 12 November 1960. The omnidirectional proton flux of greater-than-30 MeV energy during that event was $1.3 \times 10^9$ protons/$cm^2$. This value is a factor of 6.5 times less than the 29-100 MeV flux in the 3-7 August 1972 event. The highest omnidirectional flux rate of greater-than-30 MeV protons in solar cycle 19 was $1.6 - 1.8 \times 10^4$ protons/$cm^2$-sec measured during the solar particle event of 16 July 1959. This peak flux is 17.5 times less than the peak flux rate of 29-100 MeV protons observed at 2100 UT on 4 August. Comparable ratios are observed in Table 1 at the other energies. In every aspect, i.e., in peak and integrated proton flux and in hardness of the spectrum as well as the presence of intense energetic electron fluxes, the 4 August 1972 event appears to be the largest ever observed at the earth in the last two decades.

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## REFERENCES

BOSTROM, C. O., J. W. KOHL R. W. McENTIRE and D. J. WILLIAMS — 1972 — The Solar Proton Flux - August 2-12, 1972, Johns Hopkins Univ. Report, Nov. 1972.

BURROWS, J. R. — 1971 — A Review of the Magnetospheric Characteristics of Solar Flare Particles, COSPAR Symposium on the November 1969 Solar Particle Event, June 1971 (in press).

LIN, R. P. — 1970 — The Emission and Propagation of ~ 40 keV Solar Flare Electrons, Solar Physics, 12, 266.

LINCOLN, V., and H. I. LEIGHTON — 1972 — Preliminary Compilation of Data For Retrospective World Interval July 26 - August 14, 1972, World Data Center A for Solar-Terrestrial Physics, Report UAG-21, p. 121, November.

REAGAN, J. B., W. L. IMHOF and E. E. GAINES — 1971 — Satellite Measurements of Energetic Solar Protons, Alpha Particles, Electrons and of Auroral Particles during the 2 November 1969 PCA Event, COSPAR Symposium on the November 1960 Solar Particle Event, June 1971 (in press).

REAGAN, J. B., J. C. BAKKE, J. R. KILNER, J. D. MATTHEWS and W. L. IMHOF — 1972 — A High-Resolution Multiple-Particle Spectrometer for the Measurement of Solar Particle Events, IEEE Trans. Nucl. Sci., NS-19, 1, 554-561.

REAGAN, J. B., W. L. IMHOF, L. J. LANZEROTTI and C. G. MACLENNAN — 1973 — Comparisons of Interplanetary and Polar Cap Fluxes during the 4-11 August Solar Particle Events Trans. Am. Geophys. U., 54, 419.

WEST, H. I., Jr., and A. L. VAMPOLA — 1971 — Simultaneous Observations of Solar Flare Electron Spectra in Inter-Planetary Space and within the Earth's Magnetosphere, Phys. Rev. Letters, 26, 458.